PROBLEMS OF QUALITY

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IMPROVEMENT OF THE CASTING PROPERTIES OF CERAMIC SLIPS FOR SANITARY CERAMICS

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The processes of coagulation structure formation in the slips used in production of ceramic sanitary ware with additives of water-soluble chemical waste from the textile and household chemical industry are investigated. The possibility of directed correction of the rheological (casting) properties of the slips and their technological parameters is demonstrated.

Ceramic slips and in particular the slips used in production of sanitary ware are noted for their kinetic and aggregate instability, which is associated with the existence of a developed phase cleavage surface and an excess of free surface energy. Loss of aggregate stability results in deterioration of the casting properties of the slips, a decrease in the technical and economic production parameters, and deterioration of the product quality [1].

An effective way of controlling the casting properties of ceramic slips is chemical treatment. The commonly used complex alkaline diluents based on the sodium salts of inorganic acids (soda ash, water glass, sodium tripolyphosphate), owing to the high penetrating ability of hydrated sodium ions, intensify the processes of peptization and spontaneous dispersion, and a double electric layer of diffuse character impeding coagulation cohesion of the particles is formed on the surface of the disperse phase particles.

The practice of preparation and use of ceramic slips shows that simultaneous development of two stability factors (electrokinetic factor and structural mechanical factor) is needed to ensure the stability of the slips in time. The development of a structural mechanical barrier on the solid phase surface impedes realization of short-range forces of interparticle attraction, which leads to an increase in the aggregate stability of the slip.

Systematic studies carried out at the National Technical University of Ukraine to investigate the possibilities of utilization of industrial wastes in production of different kinds of

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TABLE 1

Raw material	Mass content of components in batch, %	Mass content, %									
		SiO_2	TiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	SO_2	loss after calcination
Kaolin:											
Prosyanovskii	15.0	68.30	0.13	23.70	0.88	0.51	0.11	0.39	0.09	Traces	6.24
Glukhovetskii	8.0	47.20	0.58	38.30	0.46	0.22	0.10	Traces	0.22		13.15
Novoseletskii	6.0	46.50	0.50	35.70	0.30	0.20	0.20	0.50	0.06	–	11.72
Avdeevskii quartz	19.5	99.00	Traces	0.29	0.19	0.33	0.37	–	–	–	0.24
Clay:											
Veselovskii	10.0	47.60	0.90	28.00	0.60	0.60	0.20	1.70	0.40	–	8.50
Novoraiskii	9.9	57.30	0.85	21.30	0.50	–	–	1.30	0.25	–	4.20
Lengarskii pegmatite	20.5	71.00	–	14.40	0.10	0.50	0.10	1.10	1.30	–	0.10
Article scrap	12.0	–	–	–	–	–	–	–	–	–	–

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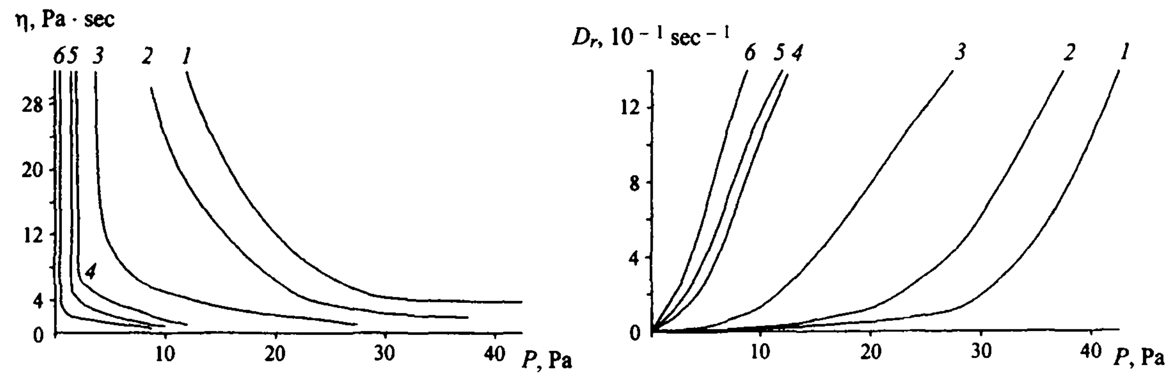

Fig. 1. Rheological curves of viscosity η and flow D_r of slips: *1*) with no additives; *2*, *3*, *4*, and *5*) with optimum additives of waste from KHCW (1.5%), SP (2.0%), ChWCW (0.5%), and DSW (1.3%), respectively; *6*) with combined addition of DSW (1.3%) and SP (2.0%).

TABLE 2

Reagent	Mass content of additives in slip, %	Rheological parameters						
		η_0, Pa · sec	η_m^*, Pa · sec	$\eta_0 - \eta_m^*$, Pa · sec	η_{ef}, Pa · sec	P_{k_1}, Pa	P_{k_2}, Pa	P_m, Pa
ChWCW	0.3	9.28	0.18	9.10	5.20	3.09	28.37	22.6
	0.4	4.64	0.20	4.44	1.51	1.54	26.28	18.4
	0.5	2.32	0.07	2.25	0.80	0.77	11.59	4.2
	0.6	11.02	0.22	10.80	5.60	3.86	29.37	24.5
	0.7	12.60	0.27	12.33	7.00	4.18	37.50	27.1
DSW	1.1	2.60	0.09	2.51	1.20	0.97	13.14	8.8
	1.2	2.32	0.08	2.24	0.60	0.77	10.05	6.2
	1.3	1.20	0.07	0.09	0.50	0.38	9.27	4.3
	1.4	2.92	0.11	2.81	1.40	0.88	15.91	9.6
	1.5	3.32	0.14	3.18	2.60	1.15	17.77	10.9
KHCW	1.3	26.69	0.30	26.39	25.00	8.90	44.38	30.4
	1.4	25.50	0.27	25.23	22.90	8.50	39.00	28.3
	1.5	23.20	0.26	22.94	20.00	7.73	38.50	24.8
	1.6	27.60	0.32	27.28	26.50	9.27	46.83	37.2
	1.7	28.09	0.35	27.74	27.80	9.82	47.97	39.8
SP	1.8	5.80	0.28	5.52	2.40	1.10	31.30	21.0
	1.9	5.20	0.21	4.99	2.20	1.00	26.50	20.0
	2.0	4.40	0.17	4.23	1.00	0.50	24.40	15.4
	2.1	7.02	0.24	6.78	2.50	1.20	35.10	21.6
	2.2	12.72	0.29	12.43	3.00	1.30	36.30	23.0
DSW + SP	1.1 + 1.8	2.32	0.09	2.23	1.00	1.15	13.02	7.2
	1.2 + 1.9	1.18	0.07	1.11	0.50	0.77	12.36	5.5
	1.3 + 2.0	1.15	0.06	1.07	0.30	0.38	9.82	2.9
	1.4 + 2.1	2.64	0.10	2.54	1.20	1.54	14.36	8.2
	1.5 + 2.2	3.02	0.12	2.90	1.60	2.32	15.98	9.8
SCW slip without additives	–	30.27	0.36	29.81	29.00	1.50	39.00	24.5

ceramics showed the advisability of introduction in ceramic mixtures of water-soluble waste containing a set of surface-active substances for interphase interactions in argillaceous systems. The environmental aspects of the problem were taken into account as well.

The present paper supplies the results of experimental research on the effect of industrial sewage from Darnitsa Silk Works (DSW), Chernigov Worsted and Cloth Works (ChWCW), sewage purification waste (SP) from Thermoelectric Plant-2 in Kiev, and waste from the Kiev Household

Chemical Works (KHCW) on the rheological properties and technological parameters of ceramic slips used at Slavyanskii Ceramic Works (SCW) producing ceramic sanitary ware. The research was carried out using the methods of fine ceramics control and rotational viscometry [2].

The batch and chemical compositions of the ceramic slips from SCW are given in Table 1.

The rheological viscosity and flow curves (Fig. 1) characterize the industrial slips containing a complex alkaline diluent as liquid-like structured systems with relatively high strength and viscosity parameters. It was found from the experimental data that the deformation processes in SCW slips attain the maximum level in terms of destruction (casting) of the coagulation-thixotropic structure for relatively high active shear stresses.

The introduction of water-soluble chemical waste in slips is usually accompanied by the effect of an adsorption decrease in strength caused by adsorption blocking of coagulation centers on the surface of disperse phase particles. It indicates system stability and is manifested by in a decrease in the viscosity and strength parameters: conditionally static P_{k_1} and conditionally dynamic P_{k_2} yield strength, plastic strength P_m, the highest (Bingham) viscosity η_0 and the lowest (Shvedov) viscosity η^*_m, viscosity anomaly $(\eta_0 - \eta^*_m)$, effective viscosity η_{ef}. Table 2 shows the effect of chemical waste on the rheological parameters of SCW ceramic slips.

The investigations performed made it possible to assess the comparative efficiency of the diluting action of industrial waste and determine the optimum reagent additives corresponding to the maximum degree of slip dilution. Thus, in the KHCW – SP – ChWCW – DSW series, with optimum industrial waste concentrations, a successive increase in diluting capacity is observed, accompanied by a sharp decrease in the active shear stresses at which the deformation evolution gradient reaches its highest values, and the effective viscosity reaches its lowest values.

The character of modification of surface tension depending on the content of the chemicals dissolved in the sewage (Fig. 2) indicates that the optimum values of chemical waste

TABLE 3

Slip	Mass content of additives, %	Moisture, %	Fluidity, sec	Thickening coefficient	Time of formation of crock 12 mm thick, h
SCW slip without additives	–	34.1	27	2.3	2.23
DSW + SP	1.3 + 2.0	31.8	9	1.7	1.40
DSW	0.5	33.5	11	1.8	1.43
ChWCW	1.3	34.0	10	1.7	1.56
KHCW	1.5	33.4	11	1.9	1.45
SP	2.0	34.4	12	2.0	2.05

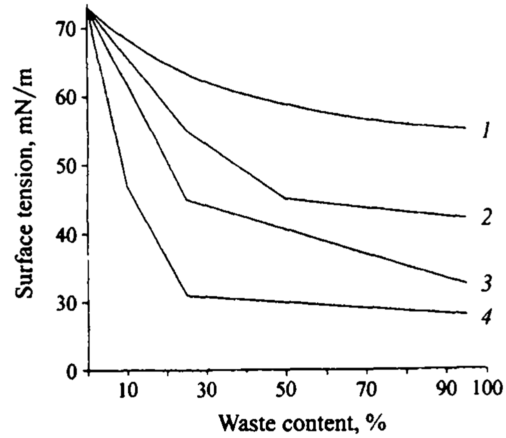

Fig. 2. Change in the surface tension of chemical waste depending on the dilution degree: *1*, *2*, *3*, and *4*) SP, DSW, ChWCW, and KHCW, respectively.

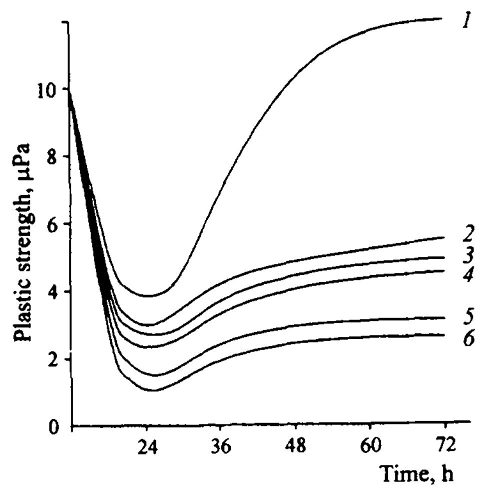

Fig. 3. Kinetics of dilution of slip with optimum chemical waste additives. Designations as in Fig. 1.

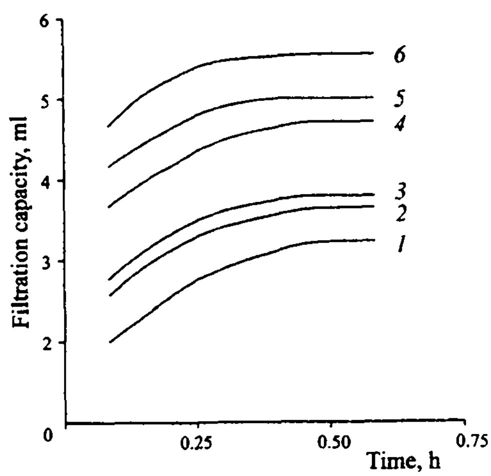

Fig. 4. Effect of optimum additives of chemical waste on filtration properties of the slip. Designations as in Fig. 1.

additives amounting to 0.5, 1.3, 1.5 and 2.0% for ChWCW, DSW, KHCW, and SP, respectively, are within the premicellar concentration region. It points to the determining role of adsorption interactions in stabilization processes. The critical micelle concentration for the KHCW and ChWCW reagents was 25%, and for DSW it was 50%.

An increase in the content of the additives introduced above the critical micelle concentration intensifies the coagulation processes in relation to the association of molecules of the surface-active components in a disperse liquid medium and on the surface of solid phase particles with a subsequent strengthening interaction between coagulation and micellar structures, which is expressed by an increase in the rheological parameters. The established regularities are also validated by the character of the changes in the technological parameters of processed slips (Table 3).

The study of the kinetics of slip dilution with optimum chemical waste additives made it possible to elucidate the advantages inherent in their application (Fig. 3). Thus, chemical treatment of technical suspensions decreases the plastic strength of the slips by 4 – 5 times compared to slips containing a complex alkaline diluent. In this case, further thickening is impeded.

The dilution of a slip caused by destruction of a coagulation structure and release of dispersion medium immobilized in structural cells positively affects the filtration properties of the slip (Fig. 4). Introduction of optimum chemical waste additives accelerates by 1.3 – 1.5 times the rate of filtration, and results in an increase in the rate of crock formation.

As a result of the investigations performed, a complex reagent of combined action was developed based on DSW and SP waste. It is capable of simultaneously forming electrokinetic and structural mechanical stability factors.

Compared to the current industrial slip, use of the slip treated with optimum additives of the above recommended composition produces an increase in fluidity by 66%, a decrease in thickening by 26%, an increase in the crock formation rate by 37%, and a decrease in slip moisture by 2.3%. All of this makes it possible to reduce the consumption of soda ash by 20 – 25%, to save material and energy resources, to increase production efficiency, and to improve the quality of the product.

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